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(54) **ORGANIC LIGHT EMISSION DIODE DISPLAY DEVICE DRIVING CIRCUIT INCLUDING A CHARGING CIRCUIT**

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CPC ***G09G 3/3233*** (2013.01); *G09G 3/3283* (2013.01); *G09G 2300/0842* (2013.01); *G09G 2310/02* (2013.01); *G09G 2320/043* (2013.01)

(58) **Field of Classification Search**
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See application file for complete search history.

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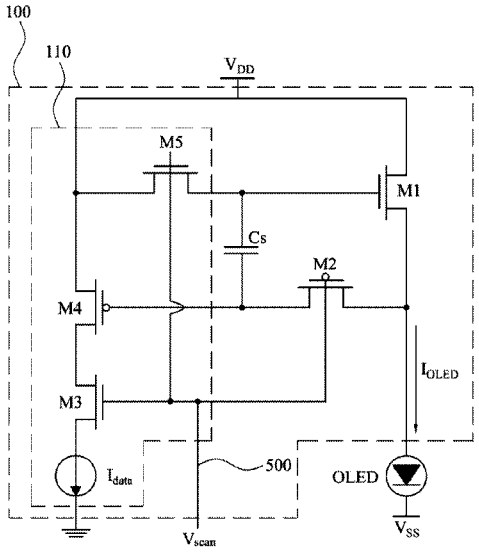
(57) **ABSTRACT**

A driving circuit includes a first transistor, a capacitor, a second transistor, and a charging circuit. The input terminal of the first transistor is electrically connected to a voltage source. The output terminal of the first transistor is electrically connected to an organic light-emitting diode. The first terminal of the capacitor is electrically connected to the control terminal of the first transistor. The input terminal of the second transistor is electrically connected to the second terminal of the capacitor. The control terminal of the second transistor is electrically connected to a scan line. The output terminal of the second transistor is electrically connected to the output terminal of the first transistor. The charging circuit is electrically connected to the first and second terminals of the capacitor, the scan line, and a current source.

5 Claims, 2 Drawing Sheets



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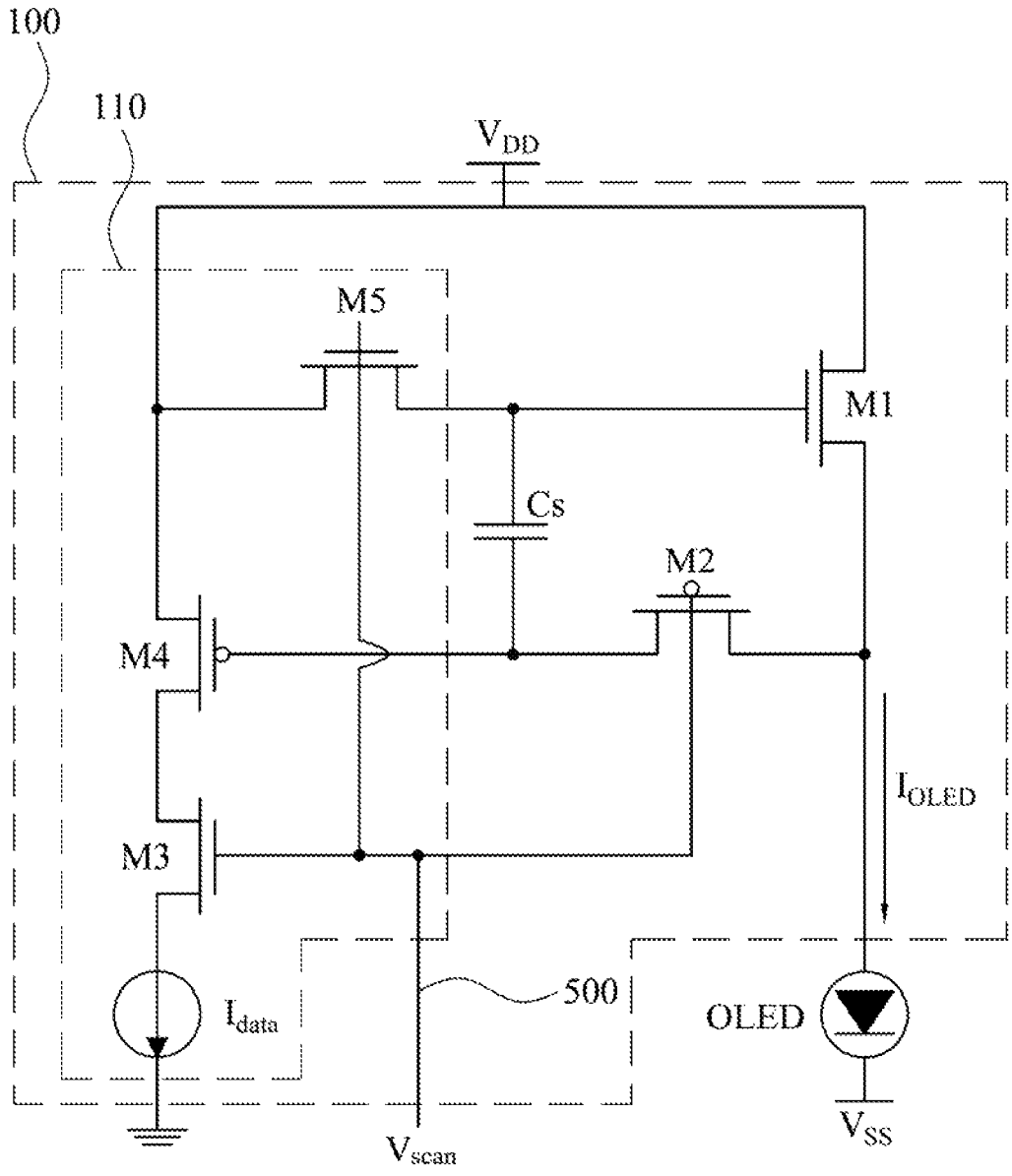

Fig. 1

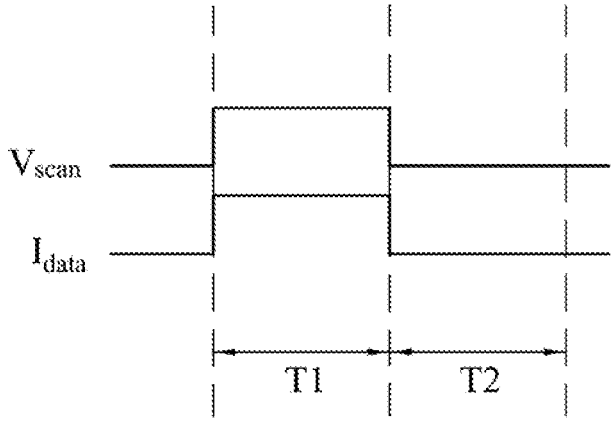
Vscan
Idata
T1
T2

Fig. 2

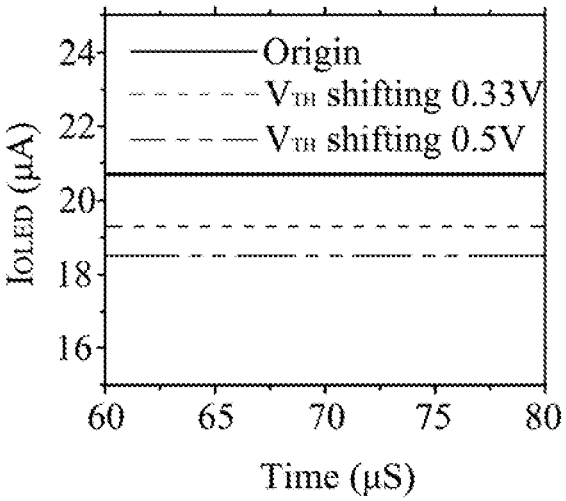
Origin
VTH shifting 0.33V
VTH shifting 0.5V
IOLED (μA)
24
22
20
18
16
60
65
70
75
80
Time (μS)

Fig. 3

ORGANIC LIGHT EMISSION DIODE DISPLAY DEVICE DRIVING CIRCUIT INCLUDING A CHARGING CIRCUIT

RELATED APPLICATIONS

This application claims priority to Taiwanese Application Serial Number 102120749, filed Jun. 11, 2013, which is herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of Invention

The present invention relates to a driving circuit and, more particularly, to a driving circuit of a organic light emitting diode.

2. Description of Related Art

Display panels utilizing current coded mode comprise at least two driving periods. One is a data writing (current programming) period. In this period, a capacitor of a driving circuit is charged by a data current, that is to say, a data voltage is written into the capacitor. The other is a light emitting period. In this period, the display panel controls the displaying brightness thereof according to the data voltage written into the capacitor.

In the foregoing data writing period, the data current can be written into the capacitor in a short time when the data current is large. Consequently, conditions associated with the data writing period are not affected. However, the data current is relatively small when the display panel needs to display a low gray level such that the time in which the data current is written into the capacitor increases substantially. As a result, the duration of the data writing period is increased substantially, and furthermore, the operation of writing data may fail.

SUMMARY OF THE INVENTION

One objective of the present invention is to provide a driving circuit. Through use of configurations and operations of the driving circuit, the problem of the time in which data current is written into a capacitor increasing substantially due to the data current being small when the display panel needs to display a low gray level is addressed. Furthermore, the duration of the data writing period can be controlled to within a time limitation to avoid data writing failure.

For achieving said purpose, one aspect of the present invention is related to a driving circuit for driving an organic light emitting diode in a display panel. The display panel comprises a plurality of scan lines. The driving circuit comprises a first transistor, a capacitor, a second transistor, and a charging circuit. The first transistor comprises an input terminal, a control terminal, and an output terminal. The capacitor comprises a first terminal and a second terminal. The second transistor comprises an input terminal, a control terminal, and an output terminal. With respect to structure, the input terminal of the first transistor is electrically coupled to a voltage source, and the output terminal of the first transistor is electrically coupled to the organic light emitting diode. The first terminal of the capacitor is electrically coupled to the control terminal of the first transistor. The input terminal of the second transistor is electrically coupled to the second terminal of the capacitor, the control terminal of the second transistor is electrically coupled to one of the scan lines, and the output terminal of the second transistor is electrically coupled to the output terminal of the first transistor. The charging circuit is electrically coupled to the first terminal and the second terminal of the capacitor, one of the scan lines, and a current source.

In one embodiment of the present invention, the second transistor is turned off according to a first scanning signal provided by one of the scan lines during a data writing period, and the charging circuit is turned on according to the first scanning signal transmitted by one of the scan lines to charge the capacitor during the data writing period.

In another embodiment of the present invention, the first scanning signal is a low level signal.

In yet another embodiment of the present invention, the charging circuit charges the capacitor according to a first current provided by the current source during the data writing period.

In still another embodiment of the present invention, the second transistor is turned on according to a second scanning signal provided by one of the scan lines during a light emitting period such that the capacitor provides a charge voltage to the control terminal and the output terminal of the first transistor.

In yet another embodiment of the present invention, the second scanning signal is a high level signal.

In still another embodiment of the present invention, the first transistor drives the organic light emitting diode according to the charge voltage during the light emitting period.

In yet another embodiment of the present invention, the charging circuit comprises a third transistor and a fourth transistor. The third transistor comprises an input terminal, a control terminal, and an output terminal. The fourth transistor comprises an input terminal, a control terminal, and an output terminal. With respect to structure, the control terminal of the third transistor is electrically coupled to one of the scan lines, and the output terminal of the third transistor is electrically coupled to the current source. The input terminal of the fourth transistor is electrically coupled to the voltage source, the control terminal of the fourth transistor is electrically coupled to the second terminal of the capacitor, and the output terminal of the fourth transistor is electrically coupled to the input terminal of the third transistor.

In still another embodiment of the present invention, the voltage source provides a second current to the organic light emitting diode during the light emitting period, wherein a relation between the second current and the first current provided by the current source is as follows:

$$I_{OLED} = \frac{K_n}{K_p} \times I_{data},$$

where I_{OLED} is the second current, K_n is a conduction parameter of the first transistor, K_p is a conduction parameter of the fourth transistor, and I_{data} is the first current.

In yet another embodiment of the present invention, the charging circuit further comprises a fifth transistor. The fifth transistor comprises an input terminal, a control terminal, and an output terminal. With respect to structure, the input terminal of the fifth transistor is electrically coupled to the input terminal of the fourth transistor and the voltage source, the control terminal of the fifth transistor is electrically coupled to one of the scan lines, and the output terminal of the fifth transistor is electrically coupled to the first terminal of the capacitor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically shows a diagram of a driving circuit according to embodiments of the present invention.

FIG. **2** schematically shows a diagram of a driving waveform according to embodiments of the present invention.

FIG. **3** schematically shows a test module diagram of a driving circuit according to embodiments of the present invention.

DETAILED DESCRIPTION

For solving problems existing in the prior art, the present invention provides an innovative driving circuit, and the driving circuit is shown in FIG. **1**. As shown in FIG. **1**, the driving circuit **100** comprises a first transistor M**1**, a capacitor C_s, a second transistor M**2**, and a charging circuit **110**. The first transistor M**1** comprises an input terminal, a control terminal, and an output terminal. The capacitor C_s comprises a first terminal and a second terminal. The second transistor M**2** comprises an input terminal, a control terminal, and an output terminal.

With respect to structure, the input terminal of the first transistor M**1** is electrically coupled to the voltage source V_{DD}, and the output terminal of the first transistor M**1** is electrically coupled to an organic light emitting diode OLEO. The first terminal of the capacitor C_s is electrically coupled to the control terminal of the first transistor M**1**. The input terminal of the second transistor M**2** is electrically coupled to the second terminal of the capacitor C_s, the control terminal of the second transistor M**2** is electrically coupled to a scan line **500**, and the output terminal of the second transistor M**2** is electrically coupled to the output terminal of the first transistor M**1**. The charging circuit **110** is electrically coupled to the first terminal of the capacitor C_s, the second terminal of the capacitor C_s, the scan line **500**, and a current source I_{data}.

When implementing the present invention, each of the foregoing transistors can be a Bipolar Junction Transistor (BJT), a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET), an Insulated Gate Bipolar Transistor (IGBT), and so on, but the present invention is not limited. In FIG. **1**, MOSFETs are used as an example to illustrate the structure of the present invention. Moreover, odd number transistors among the transistors (for example, the first transistor M**1**) are N-type transistors, while even number transistors among the transistors (for example, the second transistor M**2**) are P-type transistors. However, the scope of the present invention is not intended to be limited, and those skilled in the art can selectively adopt appropriate elements to accomplish the present invention based on actual requirements within the spirit of the present invention.

By the use of the structure of the driving circuit **100**, the driving circuit **100** addresses the problem of the time in which the data current being written into the capacitor increasing substantially due to the data current being small when the display panel utilizing current coded mode needs to display a low gray level.

For further introducing an operation mode of the driving circuit provided by the present invention, reference is now made to FIG. **2** which schematically shows a diagram of a driving waveform. As shown in FIGS. **1** and **2**, in a data writing period T**1**, a first scanning signal V_{scan} provided by the scan line **500** is a high level signal $V_{scan\text{-}high}$. The second transistor M**2** is turned off according to the scanning signal provided by the scan line **500**, and the charging circuit **110** is turned on according to the scanning signal provided by the scan line **500**. Hence, the second terminal of the capacitor C_s and the output terminal of the first transistor M**1** are electrically isolated from each other. At this time, the charging circuit **110** charges the capacitor C_s.

Specifically, in the data writing period T**1**, the charging circuit **110** charges the capacitor C_s according to a current provided by the current source I_{data}. With continued reference to FIGS. **1** and **2**, in a light emitting period T**2**, the second scanning signal V_{scan} provided by the scan line **500** is a low level signal $V_{scan\text{-}low}$. The second transistor M**2** is turned on according to the scanning signal provided by the scan line **500** such that the capacitor C_s provides a charge voltage V_{CS} to the control terminal and output terminal of the first transistor M**1**. At this time, V_{GS} of the first transistor M**1** is equal to the charge voltage V_{CS} provided by the capacitor C_s. The first transistor M**1** can drive the organic light emitting diode OLEO according to the charge voltage V_{CS}.

In addition, referring to FIG. **1**, the charging circuit **110** comprises a third transistor M**3** and a fourth transistor M**4**. The third transistor M**3** comprises an input terminal, a control terminal, and an output terminal. The fourth transistor M**4** comprises an input terminal, a control terminal, and an output terminal. With respect to structure, the control terminal of the third transistor M**3** is electrically coupled to the scan line **500**, and the output terminal of the third transistor M**3** is electrically coupled to the current source I_{data}. The input terminal of the fourth transistor M**4** is electrically coupled to a voltage source V_{DD}, the control terminal of the fourth transistor M**4** is electrically coupled to the second terminal of the capacitor C_s, and the output terminal of the fourth transistor M**4** is electrically coupled to the input terminal of the third transistor M**3**.

In this embodiment, the charging circuit **100** further comprises a fifth transistor M**5**. The fifth transistor M**5** comprises an input terminal, a control terminal, and an output terminal. With respect to structure, the input terminal of the fifth transistor M**5** is electrically coupled to the input terminal of the fourth transistor M**4** and a voltage source V_{DD}, the control terminal of the fifth transistor M**5** is electrically coupled to the scan line **500**, and the output terminal of the fifth transistor M**5** is electrically coupled to the first terminal of the capacitor C_s. As in the case of the other transistors discussed previously, in FIG. **1**, MOSFETs are used as an example to illustrate the structure of the present invention. Moreover, odd number transistors among the transistors (for example, the third and fifth transistors M**3**, M**5**) are N-type transistors, while even number transistors among the transistors (for example, the fourth transistor M**4**) are P-type transistors. However, the scope of the present invention is not intended to be limited, and those skilled in the art can selectively adopt appropriate elements to accomplish the present invention based on actual requirements within the spirit of the present invention.

For further introducing effects achieved by the structure and operation of the driving circuit **100** of the present invention, reference is now made to the following description. In the data writing period T**1**, the fourth transistor M**4** of the charging circuit **110** charges the capacitor C_s according to a current provided by the current source I_{data}. A charge formula of the capacitor C_s is follows:

$$V_{Cs} = \sqrt{\frac{I_{data}}{K_p}} + |V_{TH\_M4}| \qquad \text{formula 1}$$

where K_p is a conduction parameter of the fourth transistor M**4**, and V_{TH_M4} is a threshold voltage of the fourth transistor M**4**.

With continued reference to FIGS. **1** and **2**, in the light emitting period T**2**, the scanning signal V_{scan} provided by the scan line **500** is a low level signal. The second transistor M**2** is turned on according to the scanning signal provided by the

scan line **500** such that the capacitor C_s provides the charge voltage V_{CS} to the control terminal and output terminal of the first transistor M**1**. Meanwhile, V_{GS} f the first transistor M**1** is equal to the charge voltage V_{CS} provided by the capacitor C_s. The first transistor M**1** can drive the organic light emitting diode OLED according to the charge voltage V_{CS}. The current of the OLED is related to the V_{GS} of the first transistor M**1**. The formula of the current of the OLED is as follows:

$$I_{OLED}=K_n(V_{GS}-V_{TH\_M1})^2 \quad \text{formula 2}$$

where K_n is a conduction parameter of the first transistor M**1**, V_{GS} is a voltage between the gate and the source of the first transistor M**1**, and V_{TH_M1} is a threshold voltage of the first transistor M**1**.

Subsequently, in the foregoing light emitting period T**2**, because V_{GS} of the first transistor M**1** is equal to the charge voltage V_{CS} provided by the capacitor C_s, the charge voltage V_{CS} in formula 1 is substituted into an item of V_{GS} of the first transistor M**1** in formula 2, and the following formula is therefore obtained:

$$I_{OLED} = K_n\left(\sqrt{\frac{I_{data}}{K_p}} + |V_{TH\_M4}| - V_{TH\_M1}\right)^2 \quad \text{formula 3}$$

It is noted that a mismatch condition between the threshold voltage VT_{TH_M4} in the charging circuit **100** and the threshold voltage V_{TH_M1} in first transistor M**1** only minimally affects I_{OLED}, and so the mismatch can be ignored. To prove that the mismatch between the threshold voltage of said circuits really minimally affects I_{OLED}, Smart-SPICE with Device Model (n/pmos level=36) therein is introduced to test the driving circuit **100**, in which the following parameters are used: W/L_M**3**,**5**=8 μm/3.84 um (n-type), W/L_M**2**,**4**=8 μm/3.84 um (p-type), W/L_M**1**=50/3.84 um (n-type), C_s=0.6 pF, V_{TH}=1 or −1V, I_{data}=10 uA, V_{scan_low}=−10V, V_{scan_high}=28V, V_{DD}=10V, and V_{SS}=ground. The test results are as shown in FIG. **3** which schematically shows a test module diagram of a driving circuit according to embodiments of the present invention, where W is a width of a channel, L a length of a channel, V_{scan_low} a low level signal, and V_{scan_high} is a high level scanning signal.

As shown in FIG. **3**, the line marked by Origin is a threshold voltage V_{TH} which is not shifted. The Error-Rate of the I_{OLED} is merely 6.55% when the threshold voltage V_{TH} is shifted by 0.33V, and the Error-Rate of I_{OLED} is merely 10.41% when the threshold voltage V_{TH} is shifted by 0.5V. As this illustrates, the shift of the threshold voltage V_{TH} affects the I_{OLED} only minimally, and therefore, the mismatch of the threshold voltage V_{TH} in formula 3 can be ignored. In other words, the value of $|V_{TH\_M4}-V_{TH\_M1}|$ is smaller than the value of

$$\sqrt{\frac{I_{data}}{K_p}},$$

and so the mismatch can be ignored. With this in mind, formula 3 can be arranged as follows to obtain formula 4:

$$I_{OLED} = \frac{K_n}{K_p} \times I_{data}, \quad \text{formula 4}$$

As is evident from formula 4, the driving circuit **100** of embodiments of the present invention can adjust the ratio between I_{OLED} and I_{data} by regulating K_n and K_p. Hence, the driving circuit addresses the problem of the time in which the data current is written into the capacitor increasing substantially due to the data current being small when the display panel utilizing current coded mode needs to display a low gray level. Furthermore, the duration of the data writing period can be controlled to within a time limitation to avoid data writing failure. Moreover, when elements of the driving circuit **100** or the organic light emitting diode OLEO degrade, the degradation can be compensated by regulating K_n and K_p.

What is claimed is:

1. A driving circuit for driving an organic light emitting diode in a display panel, wherein the display panel comprises a plurality of scan lines, and the driving circuit comprises:

a first transistor comprising:
- an input terminal electrically coupled to a voltage source;
- a control terminal; and
- an output terminal electrically coupled to the organic light emitting diode;

a capacitor comprising:
- a first terminal electrically coupled to the control terminal of the first transistor; and
- a second terminal;

a second transistor comprising:
- an input terminal electrically coupled to the second terminal of the capacitor;
- a control terminal electrically coupled to one of the scan lines; and
- an output terminal electrically coupled to the output terminal of the first transistor; and

a charging circuit electrically coupled to the first terminal and the second terminal of the capacitor, one of the scan lines, and a current source,

wherein the second transistor is turned off according to a first scanning signal provided by one of the scan lines during a data writing period, and the charging circuit is turned on according to the first scanning signal transmitted by one of the scan lines to charge the capacitor during the data writing period,

wherein the charging circuit charges the capacitor according to a first current provided by the current source during the data writing period,

wherein the second transistor is turned on according to a second scanning signal provided by one of the scan lines during a light emitting period such that the capacitor provides a charge voltage across the control terminal and the output terminal of the first transistor,

wherein the charging circuit comprises:

a third transistor comprising:
- an input terminal;
- a control terminal electrically coupled to one of the scan lines; and
- an output terminal electrically coupled to the current source; and

a fourth transistor comprising:
- an input terminal electrically coupled to the voltage source;
- a control terminal electrically coupled to the second terminal of the capacitor; and
- an output terminal electrically coupled to the input terminal of the third transistor,

wherein the voltage source provides a second current to the organic light emitting diode during the light emitting

period, wherein a relation between the second current and the first current provided by the current source is as follows:

$$I_{OLED} = \frac{K_n}{K_p} \times I_{data}$$

where I_{OLED} is the second current, K_n is a conduction parameter of the first transistor, K_p is a conduction parameter of the fourth transistor, and I_{data} is the first current.

2. The driving circuit according to claim **1**, wherein the first scanning signal is a low level signal.

3. The driving circuit according to claim **1**, wherein the second scanning signal is a high level signal.

4. The driving circuit according to claim **1**, wherein the first transistor drives the organic light emitting diode according to the charge voltage during the light emitting period.

5. The driving circuit according to claim wherein the charging circuit further comprises:

a fifth transistor comprising:

an input terminal electrically coupled to the input terminal of the fourth transistor and the voltage source;

a control terminal electrically coupled to one of the scan lines; and

an output terminal electrically coupled to the first terminal of the capacitor.

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